Ergonomics Research Techniques

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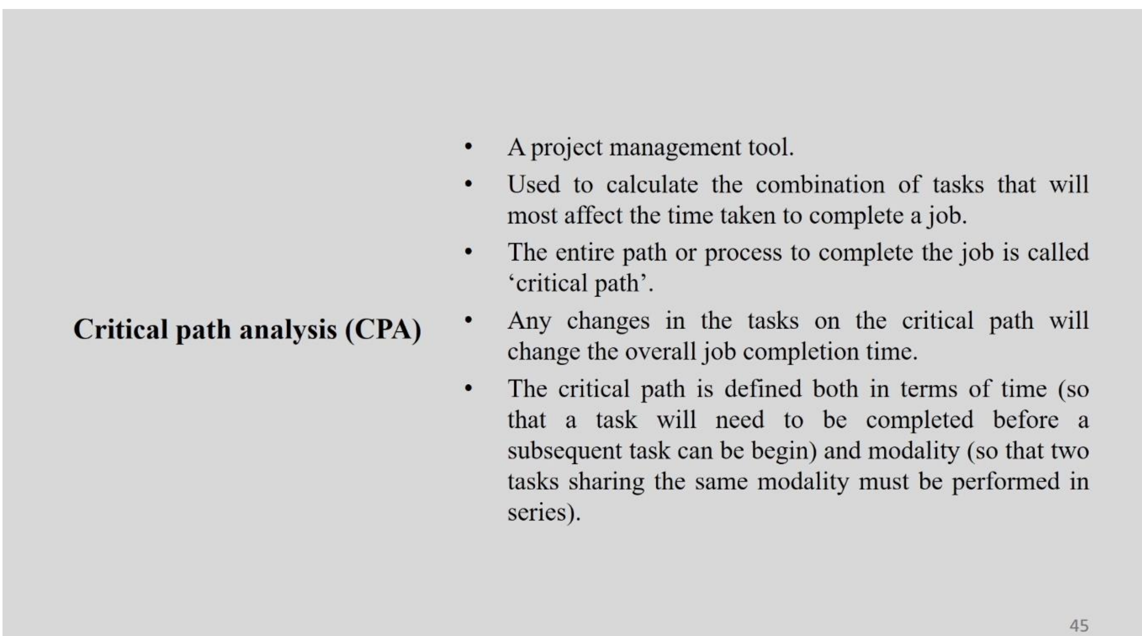
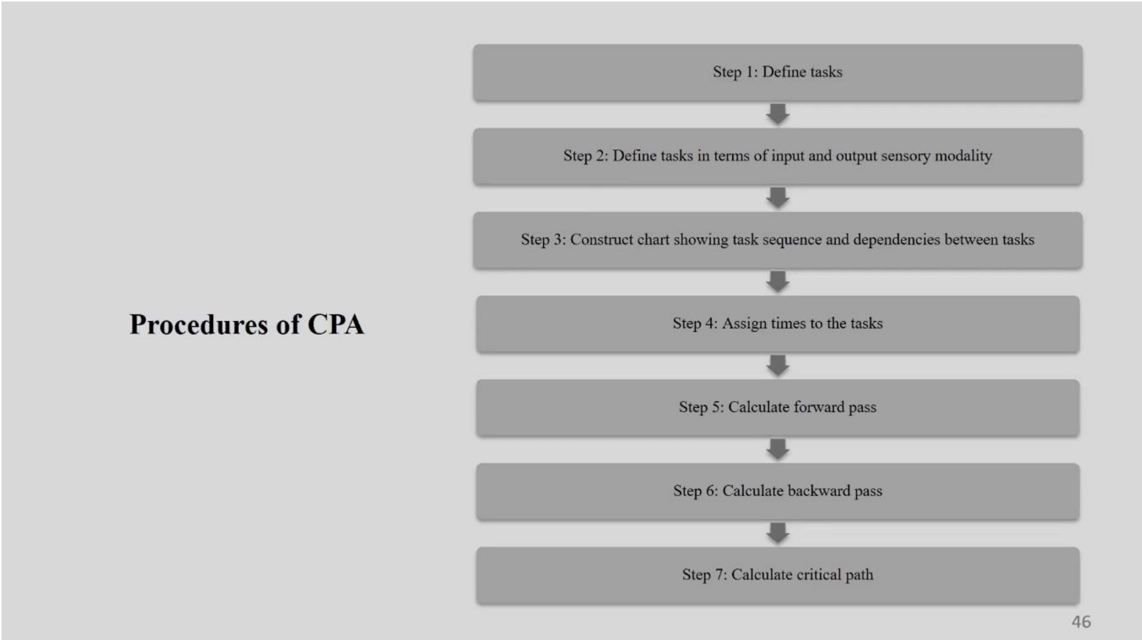
Week 10: Lec 34- Workload and situation analysis methods

Critical path analysis

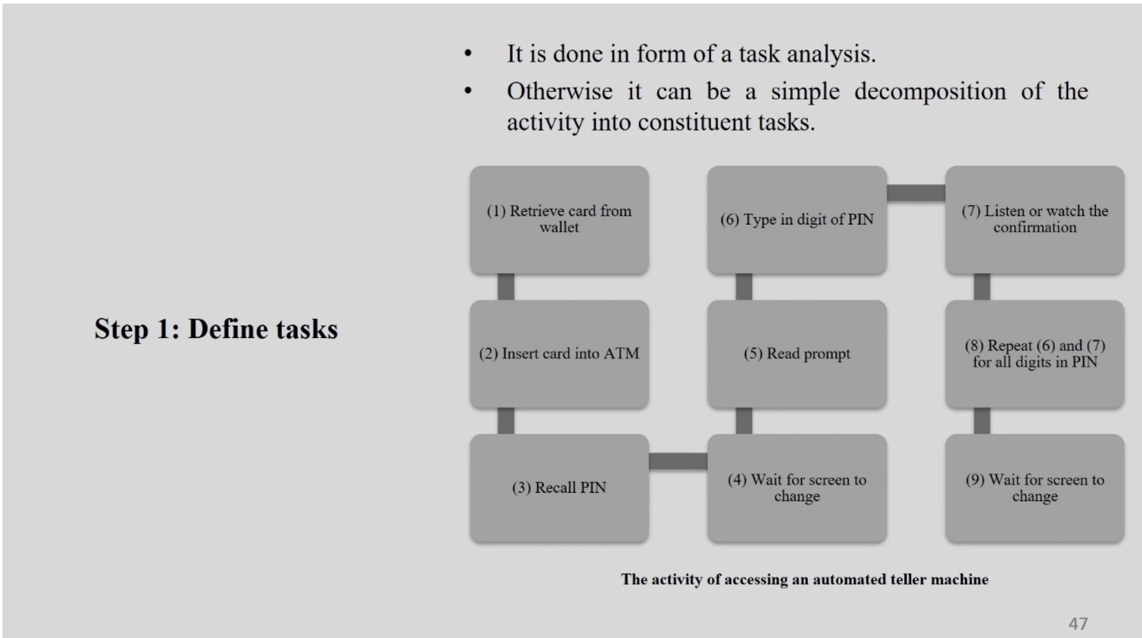
Welcome back. We were discussing from past few days regarding the mental workload analysis or assessment. So, today we will be talking about critical path analysis for multimodal activity. So, what we try to do in our earlier mental workload assessment, we try to understand suppose in NASA TLX that we have different dimensions and based on those dimensions what we did, we try to understand the mental workload. So, here in this particular method, using this particular method what we do, we try to understand in a whole process what are the critical pathways are and because of what critical incidences the process is getting affected. So, we will try to understand that, we will try to analyze that and then only we will be able to do the next step of intervention.



So, first let us understand what this tool is all about and how we should go ahead with this particular tool. Now as I mentioned this particular tool that critical path analysis, it is a project management tool. So, when you have a detailed system, so in that particular detailed system what you can do, you can have a project management tool using that particular tool, what you will do, you will have the critical pathways and you are going to identify those pathways and you are going to analyze it. So, this is used to calculate the combination of tasks. So maybe 3 tasks or 4 tasks, so to calculate the combinations of tasks that will most affect the time taken to complete the job. So, that is why I said it is critical path, because of which critical portion of the whole job is getting affected, you need to identify that using this particular tool. So, it is a, we are going to calculate the combinations of those tasks, we are going to understand the combinations of those tasks which are actually causing the time consumption in the whole job. So, the entire path or the process to complete the job is called critical path. So, the entire process, the entire process where these small combinations are there, we will be calling it as critical path. So, any changes in the task on the critical path will change the overall job completion time of course, because if you have 4 critical paths or 6 critical paths, if you do some changes in one of them, the whole time duration taken by the system or taken by that particular job to complete will change. So our objective or our intervention points are which portion of that particular path is more critical and more time consuming, we have to start our intervention program at that particular point. So, it will actually give you an indication that where the interventions are possible to start. It not only gives you an understanding of the starting of the intervention, it also help us to understand before and after the how you are making the job simple. So, what is the possible way to simplify the job? What are the elements you can take out so that the whole process of that particular job becomes simple? So, this method is very very useful when you have a long run system, when you have a big system to go ahead. So, the critical path is defined both in terms of what we call it time, what is the total time taken and what are the modalities. So, time definitely consumption or performing that particular task and the modalities, how you are going to do that. So, two major factor actually present here, one is time, second is modality. So, time says that a particular task will need to be completed before a subsequent task need to begin. So, task 1, task 2, task 3 like that you have and if task 1 time consumption is not sufficient enough to start the task 2, the task 2 will be stalled. So, it will not be able to start. So, we need to understand the time taken for the task 1 need to be within this particular period of time. Now, if we see after the critical path analysis that this task 1 is not possible to complete within this much time, then what do we have to do? We have to do some kind of intervention, so that task 2 can start on time, ok. This is the way how we use time and in modalities the two task sharing the same modalities must be performed in a particular series. If the series are not connected with each other, we may miss the sequence, ok. If we miss that, then the whole the performance of the system will deteriorate, ok. This is all about the critical path analysis.



Now, let us understand the procedure. So, of course, we will start with the defining the task. First, we have to define the task. After that defining the task in terms of input and output the sensory modalities, ok. So, like in HTA hierarchical task analysis, we start with the input, ok. What are the inputs available for that particular job and at the end of the process what I am going to get, ok. So, now if this end starting point and end point are fixed, then we can actually define this particular task. Once we define the particular task properly with input and output, we have to construct the chart showing the task sequence and you know dependencies between the task. So, there are maybe 5 tasks, ok. Now, task 1 and task 3 are interconnected. However, task 2, task 4 are independent and maybe the result of task 1 and task 2 is connected with the task 5, ok. So, how they are dependent on each other? Once we understand the sequence of these tasks, we will be able to connect them. So, assign once we have once we have the sequence, once we establish the dependency on each other, what we will do? We will assign the time, what is required for each task, ok. Task 1, this much time, task 2, this much time, like that we will be assigning it. Now, once we assign the whole numbers like you know in minutes or seconds, whatever it is, whatever unit you are using, once we assign it, what you have to do? You have to calculate the forward pass because from one to another, how it is getting forwarded, forward pass and the backward pass because it may happen in a particular system, there is a feedback mechanism. So, when one information is passing from one task to another, so how it is happening and how the you know feedback is coming back to the another task. So, calculate the forward pass and calculate the backward pass. So, let us again recall the whole process. First, we are defining the task, we are defining the specific input and specific output, then we are constructing the you know chart in a particular sequence which shows the dependency of different task in a whole job. Once we have that chart ready, what we have to do? We have to assign the time taken for each task. Once that time taken for each task is given, then we have to calculate the forward pass and backward pass. Once this whole thing is ready, ultimately we have to calculate the critical path, ok. So, this is the whole process of doing the critical path analysis.



Now, let us go ahead with the proper steps like you know explaining each steps in detail, ok. So, first is the defining task. It is done in the form of task analysis, any task analysis, ok. So, it is not that always you need to do hierarchical task analysis. However, if you can do it that is better, but here also flow diagram sometimes work. So, otherwise it can be a simple decomposition of the activity into a constituent task, ok, decomposition one by one, 1, 2, 3, 4, 5 like that. So, now here in this particular example for an automated Taylor machine, what we did like you know always everybody knows this example probably, you know how we use our ATM, ATM machine, ok. So, here we start with the retrieve, you know, your card is with you in your wallet or in your bag or in your pocket. So, you retrieve that card from wallet, insert that card into ATM machine. So, this way we are actually decomposing the whole task. Then recall the pin because you have to give the pin to the ATM. Then wait for a screen to change because once you give an input to the machine, it will give an output. So, there is a pause, ok, there is a time lapse. Then whatever information is getting displayed in the screen, you have to read it promptly. Now, here why prompt? If you look at the ATM behavior, you see if you do not respond within certain amount of time, it will the that whole system will start from the beginning, right. So, this particular, so that is why I mentioned, read the instruction very promptly, type in digit that particular pin whatever is mentioned over there, then listen or watch the, you know, confirmation whatever different machine perform differently. Repeat the 6 and 7 because you know, if it is wrong, then again you have to retype. If it is correct, then you go ahead something like that. And again, you can wait for the screen to change for the next step. This is only how you are accessing the ATM. Now, after that money transaction or balance inquiry or for other thing, you have steps to follow. So, this is simple portion of while using ATM, how you are actually accessing the ATM, ok. So, this is the decomposition. Input, it starts from the, where it starts? It starts, how you are recalling your wallet, you know, retrieving your card from the wallet and it ends after you give the pin to the ATM, you are waiting that you know, the screen to be changed to the next step, ok. So, this is for example, we are taking this particular portion and we are defining the task.

Step 2: Define tasks in terms of input and output sensory modality

- Define tasks in terms of input and output sensory modality:
  - Manual (left or right hand)
  - Visual
  - Auditory
  - Cognitive
  - Speech

Task step	Manual- L	Manual- R	Speech	Auditory	Visual	Cognitive	System
Retrieve card	X	X					
Insert card		X					
Recall PIN						X	
Screen change							X
Read prompt					X		
Type digit		X					
Listen for beep				X			
Screen change							X

Relating task steps to modality

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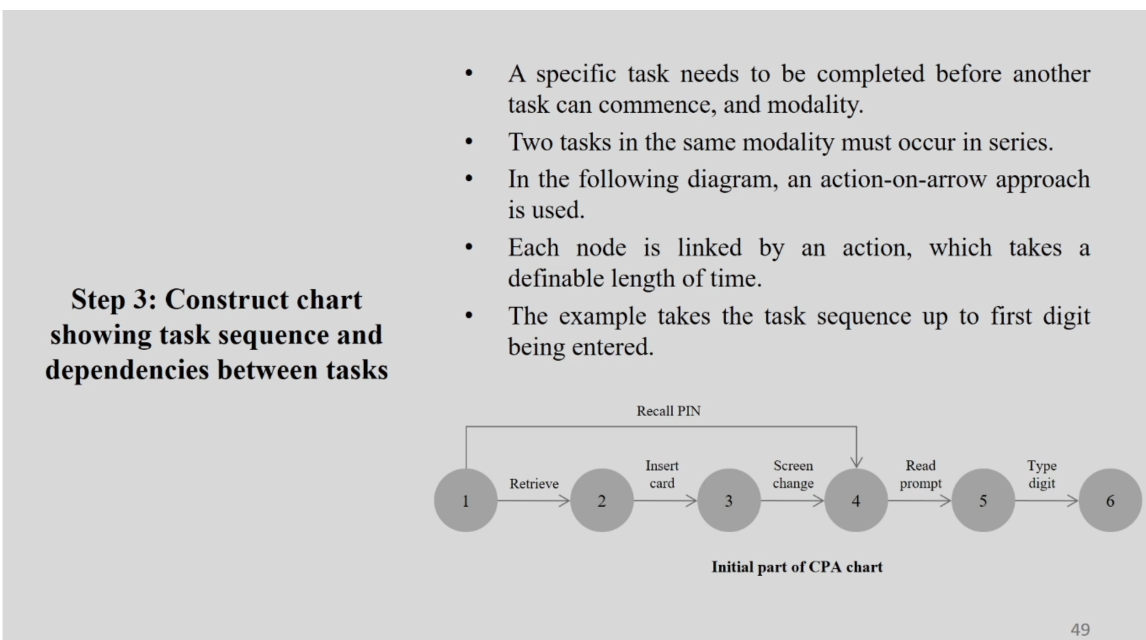
Now, here in the second step, define the task in terms of input and output. First you define the task. So, you have a flow chart, ok. Now, here for each portion, what is your input, what is the output, what is your input and what is your output. So, in terms of input and output, in terms of sensory modalities. Now, let us understand. What we have done over here in the left, this particular column, the same task, whatever is this 1, 2, 3, 4, 5, 6, 7, 8, 9, right. So, we have given these things, ok, right. Now, define the task in terms of input. Normally, these are the things possible for this particular example. For other example, maybe it is different. So, here it is some kind of manual activity when you are retrieving the card, either using your left hand or right hand or both hand. Then for, you know, then you may have some visuals like through vision, you are getting responses also from the auditory, then cognitive and then speech, ok. Now, let us understand for each step like retrieve card, what are the sensory inputs are there. Now, when I am talking about retrieve card, your left hand and right hand both are involved. However, the speech, auditory, visual, cognitive and any other system may not be active, ok. Whereas, in inserting that particular card in the machine, if you are a right handed person, you are going to use your right hand. Whereas, if you are a left handed person, you can go for the left hand. Now, it depends, ok. For this particular example, it is a right handed person. Then recall the pin, recall the pin is absolutely cognitive, right. You are actually remembering that what your pin is. So, here it is cognitive, you are giving that. Then screen change, screen change means the human, the operator is not doing anything. They are just waiting that machine to respond, ok. When you are waiting to machine to respond, that means, system is actually active, ok. Now, read promptly. How you are reading? You are looking, getting the information. So, you are perceiving the information through your vision, right. So, this sensory information is required. So, it is visual. Now, again what you are doing? You are typing the digit because you are typing the pin. Whatever you remembered in this particular step, you are typing the pin. If it is a right handed person, of course, he or she will do with the right hand. Then you are waiting the response. Now, here two things possible. Sometimes there is no auditory signal, ok. In some certain machine, there is no auditory signal. So, maybe only visual. Some cases it is auditory. So, for this particular example, it was auditory. That is why we mentioned here auditory and then screen change. Again, it is going for the system. So, this way we are actually creating a chart, ok, for each task, each small elements, how they are getting responses. So, sensory input and output, clear. So, relating the task steps to the modalities. So, modalities we are trying to identify through this particular step.



Now, the next step is third step, the construct the chart showing task sequence and the dependence between the task. So, first you constructed it. Now, you are giving numbering 1, 2, 3, 4 sequence and how that sequence is dependent on each other. Now, let us understand for this particular example. So, a specific task needs to be completed before another's task can commence and the modalities need to be finalized or need to be mentioned, ok. Two tasks in the same modalities must occur in a series. So, if it is a manual and right handed, using your right hand you have to do. So, it has to come one after another. Both, if comes together, you will not be able to perform. The operator will not be able to perform, right. So, the task in the same modalities must occur in a particular series. So, in the following diagram, an action on arrow approach is used. So, you can see these arrows, right, these arrows we gave, ok. Each node is linked by an action which takes a definable length of time and the example takes the task sequence up to a first digit being entered, ok, till here. Now, let us understand. So, retrieving card from the wallet, so that is 1, then you are inserting the task, so second, then screen change and then actually 4. Now, recall is connected here. So, you are doing the activity, you are actually using your hand to take the card out, also simultaneously you are remembering the pin to be fit here, ok, to be fit here. So, once you give that particular pin, then you are actually waiting for the screen to be changed and once there is a screen change, you are actually reading it very promptly and you are giving the pin to a team, ok, so that it can go to the next step. So, this way initial part of the CPA can be, you know, can be chucked out, can be drawn, fine. So, this is the constructing the chart showing the task sequence and dependency between each other. So, here this portion is dependent on this, ok. You should remember it, your pin, otherwise you will not be able to proceed further.

Step 4: Assign times to the tasks

- Following table provides a set of times.
- The previous diagram is redrawn in form of a table which helps in the following steps.

Task step	Duration	Earliest step	Latest step	Earliest finish	Latest finish	Float
Retrieve card	500 msec					
Insert card	350 msec					
Recall PIN	780 msec					
Screen change	250 msec					
Read prompt	350 msec					
Type digit	180 msec					
Wait for beep	100 msec					

Critical-Path Calculation Table: Forward Pass

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Now, once it is there, then actually what you are doing, you are assigning the time to this particular task, ok. Here for this particular example, we calculated in the millisecond, so retrieving card, insert card, recall pin, screen change, read promptly, type the digit and wait for the beep. So, for all these things, we have calculated these milliseconds, ok, time. Now, what I suggest over here, it is not possible to get all these values, you know, physically on the spot. So, whenever we are actually collecting data for such cases, what we suggest, we do a proper video recording of the whole process and once we are back to the laboratory, we take the data from the videotape. It is not that we suggest someone to go on the field and collect all these information. So, there are a lot of, there will be lot of chances to, you know, get wrong data. So, always from the video recording, you should retrieve this type of data. So, this previous diagram is redrawn in the, in this particular form of a table, which helps in the following steps. So, you are actually getting the time requirement for each step which is being performed in the ATM, ok.

Step 5: Calculate forward pass

- Begin at the first node of the previous figure and assign an earlier start time of 0.
- The finish time for task from this node will be 0 + the duration of the task step.
- Enter the value in the table and proceed to the next node.
- The earliest finish time of one task becomes the earliest start time (EST) for the next task.
- A simple rule is to calculate EST on the forward pass.
- When more than one task feeds into a node, take the highest time.

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Now, once this is done, what you have to do, we calculate the forward pass and calculate the backward pass. Now, let us understand it in detail. So, begin at the first mode of previous figure and assign an earlier start time is 0, ok. The finish time for the task from this node will be 0 plus the exact duration of that particular task step. So, retrieve task suppose 50 millisecond. So, it started with 0, 500 millisecond, ok. Then next step is insert card 350 millisecond. So, before I go for recalling the test, how much time I have 500 plus 350, 850 milliseconds, ok. So, it is a plus, ok. Enter the value in the table and proceed to the next node. The earliest finish time of one task become the earliest start time for the next task. So, earliest estimated time for screen, what will be 500 plus 350 plus 780. So, earliest start time for screen change is 500 millisecond plus 350 millisecond plus 780 millisecond. That is the possibilities, ok. That is the possibilities for earliest start time for screen change, earliest start time for screen change, fine. A simple rule is to calculate EST on the forward pass because it is a plus, plus, plus. When more than one task feed into a mode, it takes the highest time always because you know you have more than one or two. Now, calculate the forward task. So, you know here you can see as I mentioned for this it is 850, then it is again 0, right. Then this because plus this, plus this, plus this is this, right. Like that you have to do the calculation, clear. Because this recall, this recall you know it is like you know when you are here you can do this as well, right. You can do that as well because when you are actually retrieving that card, you are actually remembering. So, maybe it is 0 for this particular case, ok. So, that way you can do the calculation.

Step 6: Calculate backward pass

- Begin at the last node and assign a latest finish time.
- To produce the latest start time, subtract the task duration from the latest finish time.
- The time on the connection becomes the latest finish time (LFT) for that task.
- When more than one task feeds into a node, take the lowest time.

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Now, calculate the backward pass. Begin at the last node and assign the latest finish time, whatever the maximum possible, ok. So, to produce the latest start time, subtract the task duration from the latest finish time. So, the time on the connectionon that particular connection became the latest finish time for that particular task. When more than one task feeds into a particular node, take the lowest time. We have to take the lowest value.

Step 6: Calculate backward pass

Task step	Duration	Earliest step	Latest step	Earliest finish	Latest finish	Float
Retrieve card	500 msec	-	0	-	500	-
Insert card	350 msec	-	500	-	850	-
Recall PIN	780 msec	-	320	-	1100	-
Screen change	250 msec	-	850	-	1100	-
Read prompt	350 msec	-	1100	-	1450	-
Type digit	180 msec	-	1450	-	1630	-
Wait for beep	100 msec	-	1630	-	1730	-

Critical-Path Calculation Table: Backward Pass

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So, for this also you can see the calculation. Calculation is this. This way you can calculate it. For latest here it is 0, then you have here it will come here 350. It will be 350, ok. And then you can go ahead, ok. This is typing message. It is 350, ok. Then you can go ahead. This is called backward pass.

Step 7: Calculate critical path

- The critical path consist of all nodes that have zero differences between EST and LFT.
- The task step on "recall PIN" has a nonzero float, which means that it can be started up to 320 msec into the other tasks without having an impact on total task performance.
- It is possible to perform the calculations using commercial software; Microsoft Project TM.

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Now, once this table is ready, actually what you have to do? You have to identify the critical path. The critical path consists of all nodes that have 0 difference between EST and LFT, ok. So, earliest and latest, that portion you have to find out. So, critical path consists of all nodes that have 0 difference, that has 0 difference, ok. So, the task step on recall pin has a non-zero float which means that it can be started up to 350 millisecond into the other task without having an impact on the total task performance. You can see if you this particular, right. So, here not, so here if you remember this point, you know, this particular pin, after 350 millisecond as well you have no impact on the whole process. You can remember it at the very beginning when you are actually taking out the card. However, if you do not remember, but you remember just while inserting that card and getting that information at that point also if you remember that also will work and there will be no delay in the whole job, ok. So, that I mentioned, so it is possible to perform the calculation, sorry, it is possible to perform the calculations using commercial software and you know sometimes we have some kind of arrangement, you can write your own logic algorithm and you can have it in your computer as well, you can do this. So, we have different types of software for this calculations, ok.

Step 7: Calculate critical path

Task step	Duration	Earliest step	Latest step	Earliest finish	Latest finish	Float
Retrieve card	500 msec	0	0	500	500	0
Insert card	350 msec	500	500	850	850	0
Recall PIN	780 msec	0	320	780	1100	320
Screen change	250 msec	850	850	1100	1100	0
Read prompt	350 msec	1100	1100	1450	1450	0
Type digit	180 msec	1450	1450	1630	1630	0
Wait for beep	100 msec	1630	1630	1730	1730	0

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Now, calculate the critical path under this, here there are the floats, so these are 0, ok. So, you now you understood how this things to be done. So, where is like, you know, wherever these 0 differences between EST and LFT, there are the critical paths. So, if these are the 0s, right, these are the 0s, that means these are the critical paths and you will get an impact if there is a problem in these particular portion of your task, ok.

Advantages

- Structured and comprehensive procedure.
- Can accommodate parallelism in user performance.
- Provides reasonable fit with observed data.

Disadvantages

- Can be tedious and time-consuming for complex tasks.
- Modality can be difficult to define.
- Can only be used for activities that can be described in terms of performance times.
- Times not available for all actions.
- Can be overly reductionist, particularly for tasks that are mainly cognitive in nature.

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Now, what is the advantage? Structured and comprehensive procedure can accommodate parallelism because you can go one by one in a parallel sequence in user performance and also it provides reasonable fit with observed data, that is why these are, you know, these are very much beneficial and you can take advantage of these methods for such cases. Whereas, we have some kind of disadvantage, it is very much tedious and time consuming because you have to take the videos several time because it is not very easy to retrieve the data from the video. Modality can be very difficult to define because many cases, you know, simultaneous things are happening, ok. Sometimes the inputs are varied in nature, so those cases modality identification is difficult, can only be used for activities that can be described in terms of performance time. If there is no task which is being described, which is possible to describe in terms of performance time, then we will not be able to use this particular tool. Time is not available for all actions, if there are some action which will not have any time to perform, then you cannot use it and can be overly, you know, reductionist particularly for tasks that are mainly cognitive in nature, ok. For such cases, we will not be able to use this particular method to understand the criticality of the task. So, let us understand that what is required. So, it depends on the the job like, you know, if the task is real complex, then it will take a lot of time for the researcher to understand and giving the mass. So, the, you know, training time, it depends on the how complex the job is, ok. We really cannot say it is 2 hours, 3 hours or 4 hours, it absolutely depends how the complex the job is and it needs only pen and paper. So, you need to actually calculate all those numbers, right and you have to give the input and soft, if you have a software initial numbering, initial time calculation, any way you have to do, ok. Once you have that, maybe you can get the values or critical paths from those softwares, ok. So, these are the things available for the critical path analysis based on the context, based on the type of research you are doing, you have to choose that is this particular method or particular tool useful for your mental load assessment or not, ok. That is all and next we will be doing for the situation awareness measurement, ok. So, that is all for today and I again as I do for all other methods, I suggest everyone to practice it with your own example, ok. You take any situation, you take any context and try to implement it. So, here I used ATM, ATM where you can, which you can do by yourself or maybe I did from inserting the card till, you know, next after giving the pin, what is happening. You can go ahead further, if you want to withdraw money, you can take those steps and you can do the analysis. Like that you can perform and in the discussion session, let us discuss it if you find any difficulties further, ok. Thank you for today, we will start the next class tomorrow. Thank you. .